P-P and P-S inversion of 3-C seismic data: Blackfoot, Alberta

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ABSTRACT

P-P and P-S inversion was applied to the vertical and radial components of the Blackfoot 3-C survey, to yield P velocity, S velocity and Vp/Vs. This work was done as part of an ongoing inversion project which will compare the Velocity estimates from different frequency ranges. The results of the work to this point indicate that for the 10 Hz data, both the P-P and P-S inversion methods provide good velocity values. The resulting Vp/Vs estimates showed a Vp/Vs decrease over the zone of interest. Pre-inversion processing flows were developed for both the P-P and P-S data.

INTRODUCTION

Pre-stack seismic data were acquired from the 10 Hz Blackfoot data set, with preliminary processing applied. The data was then processed for inversion using techniques that reduced random noise, positioned the data correctly, and broadened the frequency band. For the P-P data this was a simple process - P-P inversion can done post-stack. The P-S data however, required a more unusual approach. Because the P-S inversion algorithm used in this experiment was applied pre-stack, processing goals had to be met pre-stack as well.

PROCESSING OF P-P DATA

The P-P data was obtained as a set of CDP gathers with the following processing applied (Gorek, 1995):

Geometry Assignment

Trace Edits

Shot-mode FK Filter

Spherical Divergence

Surface-Consistent Spiking-Decon

TV Spectral Whitening

Statics

NMO

The P-P data were then processed for input to inversion. The goal of this processing was to balance the reflection amplitudes, improve the signal to noise ratio, and position the reflection energy correctly. This was achieved using the following flow:

Surface Consistent Amplitude Correction - Shot, Receiver, Channel, CDP

CDP Stack

FX Decon

Phase Shift Migration

Spiking Decon

Figure 1 is the resulting migrated section. The target Glauconitic Channel (Miller et al, 1995) can be seen to the right of the 08-08 well, at the Mississippian level.

INVERSION OF P-P DATA

Post-stack inversion was performed on the P-P section. P sonic logs from wells 14-09 and 08-08 were projected onto the line (Miller et al, 1995), correlated to the P-P section in time (Figure 2) and were used as initial P velocity estimates.

Inversion testing was done using 3 different P-P inversion algorithms available in Promax. Inversions compared were: Time Domain Recursive, Frequency Domain recursive and Sparse Spike. The Frequency Domain Recursive inversion was found to provide the most stable results over the zone of interest, and was therefore selected for inversion of the P-P data. The following P-P inversion flow was followed.

Band-Pass filter (5-10-75-85)

Frequency Domain Recursive Inversion - Frequency Ranges to Honour: 10 - 85 Hz seismic, 0-10 Hz initial estimate

Figure 3 shows the resulting P velocity estimate, with wells 14-09 and 08-08 overlain for comparison. Note the clearly resolved channel to the right of well 08-08.2).

PROCESSING OF P-S DATA

The P-S data was obtained as a set of CCP gathers with the following processing applied (Gorek et al., 1995):

Geometry Assignment

Asymptotic Binning, Vp/Vs=2.22

Trace Edits

Shot-mode FK Filter

Spherical Divergence

Surface-Consistent Spiking-Decon

TV Spectral Whitening

Statics

NMO

The P-S data were then processed for input to inversion. The goals of this processing, as for the P-P data, were to balance the reflection amplitudes, improve the signal to noise ratio, and position the reflection energy correctly. Because the P-S inversion is applied pre-stack, processing had to be applied pre-stack. This was accomplished by sorting and then stacking the data into common-offset panels, and applying each processing step to each offset panel. The following processing flow was used:

Common Offset Binning: Bin width = 40m

FX Decon of Common Offset Planes

Phase Shift Migration of Common Offset Planes

Discard Offset s: 0m - 400m

Spiking Decon of Common Offset Planes

Figure 4 is a stack section of the P-S data, offsets 0 - 400 m were discarded as they degraded the quality of the stack. A comparison of this section to the equivalent section from Gorek, 1995, shows that pre-stack application of noise reduction, migration and signal enhancement achieves almost identical results to those of post-stack application.

INVERSION OF P-S DATA

Inversion was performed on the P-S section. A detailed description of the P-S inversion algorithm is described in Ferguson, 1995. Input to the P-S inversion is summarized below:

CCP gathers

P velocity correlated to P-S time

Initial S velocity

The CCP gathers were obtained using the processing flows described above. The P velocity used was the P velocity of figure 3, and was correlated to P-S time using the horizon interpretations of Figures 5 and 6. During this process, a sinc function interpolator was used to resample the stretched P velocity. Initial S velocity estimates were derived for the two well locations, by scaling the P sonics with the Vp/Vs ratios implied by the horizon picks of Figures 5 and 6. The resulting S sonics were correlated to the P-S data using the same process as for the P inversion velocity - using the horizon picks to stretch the velocity followed by sinc function interpolation.

The P-S inversion proceeded as follows:

Band-pass Filter: 5-10-40-50

P-S Inversion: Reflection scalar = 0.05, Error Constraint = 15%

Figure 7 shows the resulting S velocity estimate, with wells 14-09 and 08-08 overlain for comparison. The target channel is much less evident on this section than on the P-P inversion.

The velocities of Figures 7 and 3 were then used to compute a Vp/Vs section. Figure 8 is a Vp/Vs section derived from the P-P and P-S inversions. The ratios tend to fall into the range of 1.5 to 2.5, with anomolously high values up to 9.0 below the Manpk level. Figure 9 is a close-up of the Vp/Vs section, amplitudes above 3.0 are clipped. This close-up reveals much greater detail through the zone of interest (1400 ms - 2000 ms) and shows areas of Vp/Vs decrease in the zone just above the Mississippian.

CONCLUSIONS

The vertical and radial components of the 10 Hz Blackfoot line were inverted to provide estimates of P velocity, S velocity and Vp/Vs. It was found that P-P and P-S inversion provided good velocity estimation, and the resulting Vp/Vs showed decreases over the zone of interest. Pre-inversion processing flows were developed to be employed in further inversion work.

REFERENCES

Ferguson, R. J., and Stewart, R. R., 1995, Constrained inversion of P-S seismic data: CREWES Project Research Report, v.8, chpt. 18.

Gorek, S. J., Stewart, R. R., and Harrison, M. P., 1995, Blackfoot processing: CREWES Project Research Report, v.8, chpt. 38.

Miller, S. L. M., Aydemir, E. O., and Margrave, G. F., 1995, Preliminary interpretation of P-P and P-S seismic data from the Blackfoot broad-band survey: CREWES Project Research Report, v.8, chpt. 42.

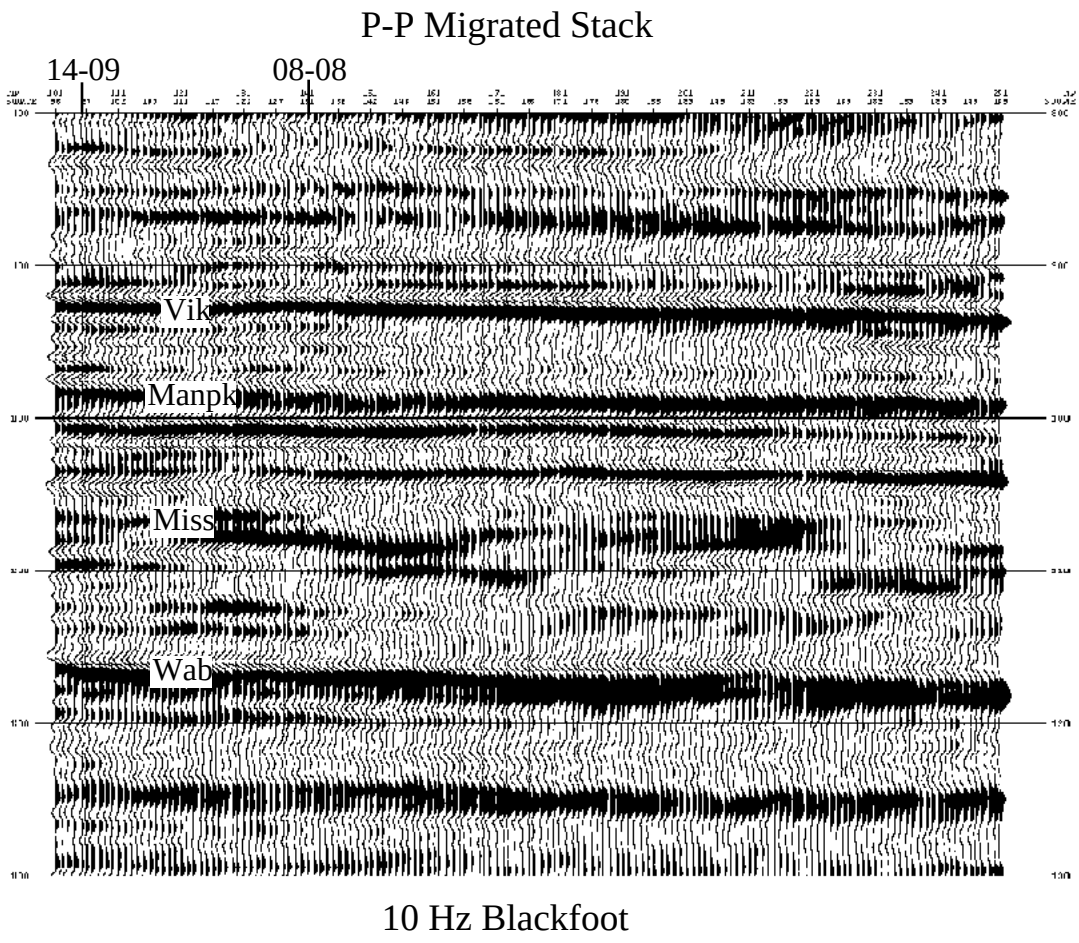
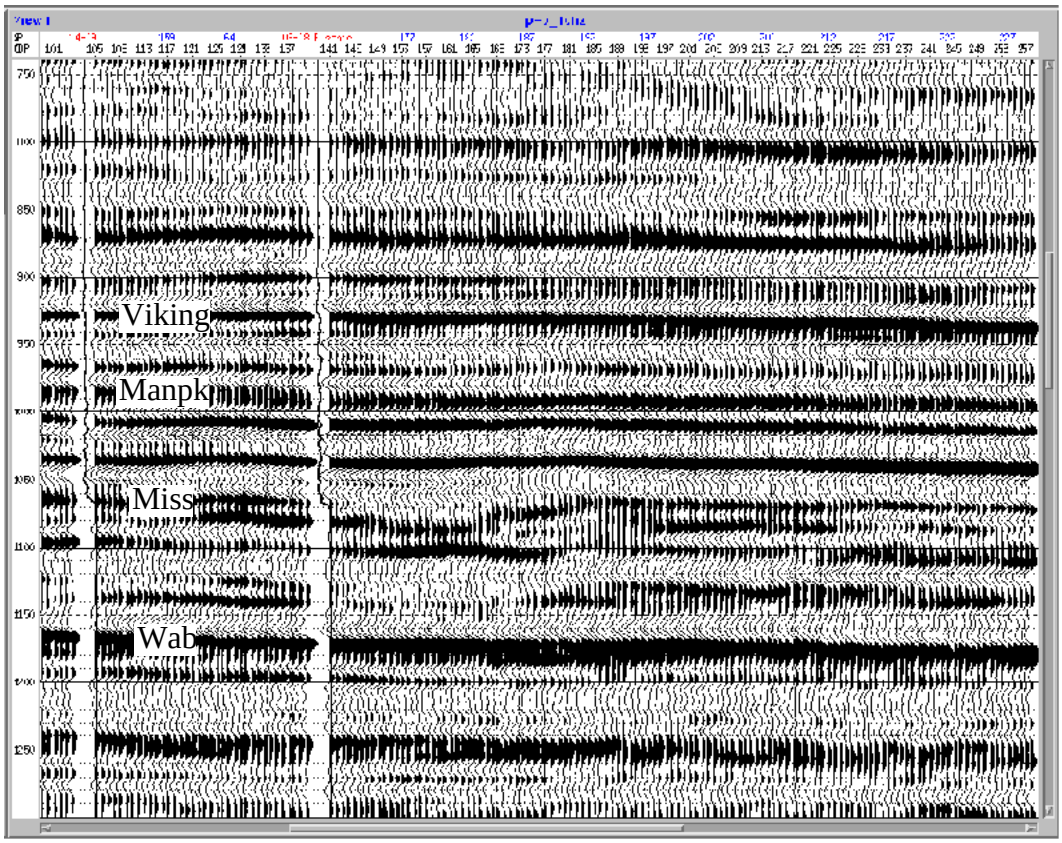


Fig. 1. Vertical component section. This display has been filtered and AGC scaled for viewing only. No AGC scaling was applied prior to inversion. P sonic log locations of wells 14-09 and 08-08 are indicated. The Glauconitic Channel (Miller et al, 1995) can be seen to the right of the 08-08 well, at the Miss level.

P sonics Correlated to P-P Section



10 Hz Blackfoot

Fig. 2. Correlation of P sonics to P-P stack section. The resulting stretched P sonics were used as initial velocities for P-P inversion

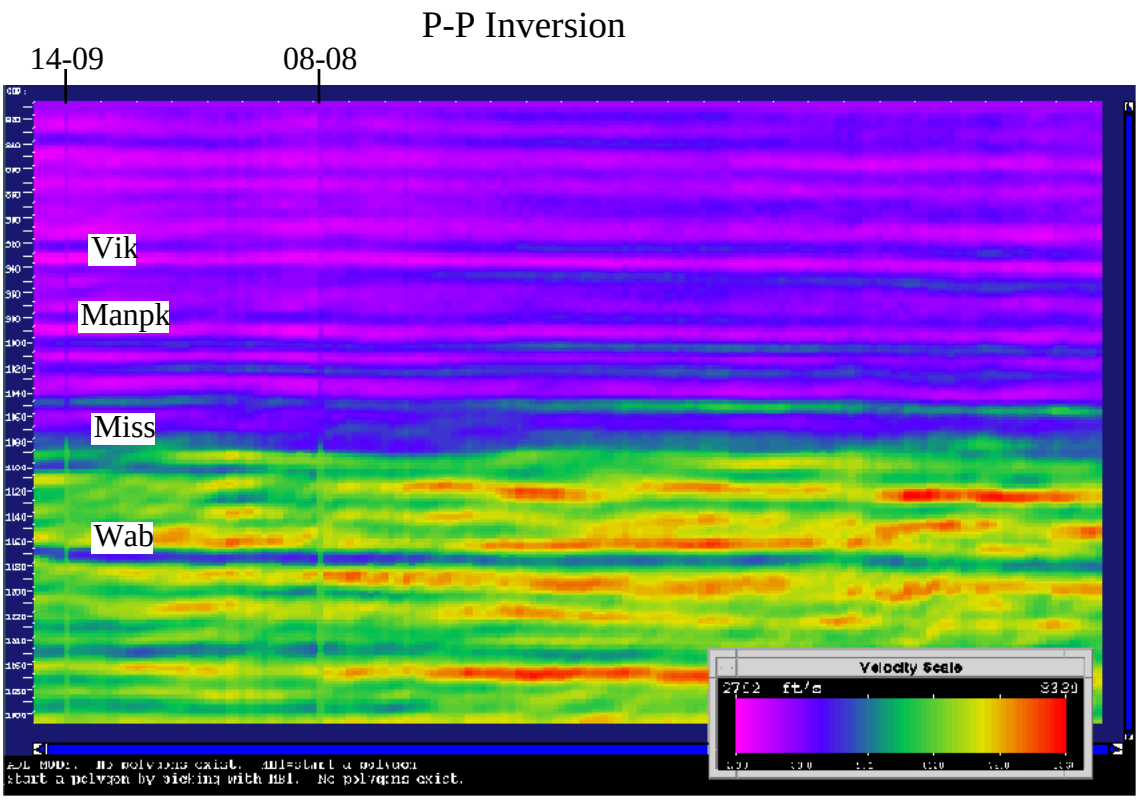


Fig. 3. Inversion of P-P data. P sonics 14-09 and 08-08 are overlain for comparison. The CDP range is 101 on the left and 251 on the right. The target channel, to the right of 08-08 at the Miss level, is clearly resolved.

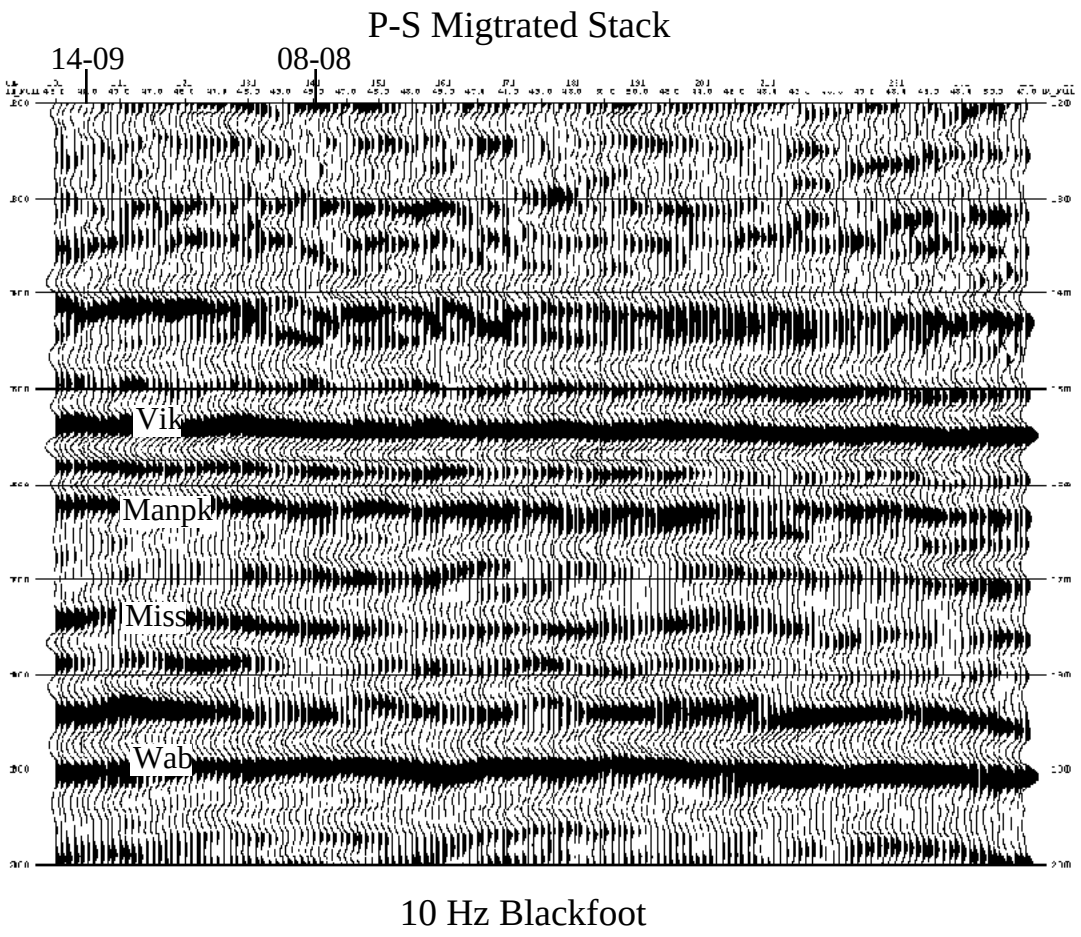


Fig. 4. P-S stack section. FX decon, Migration and signal enhancement all done pre-stack.

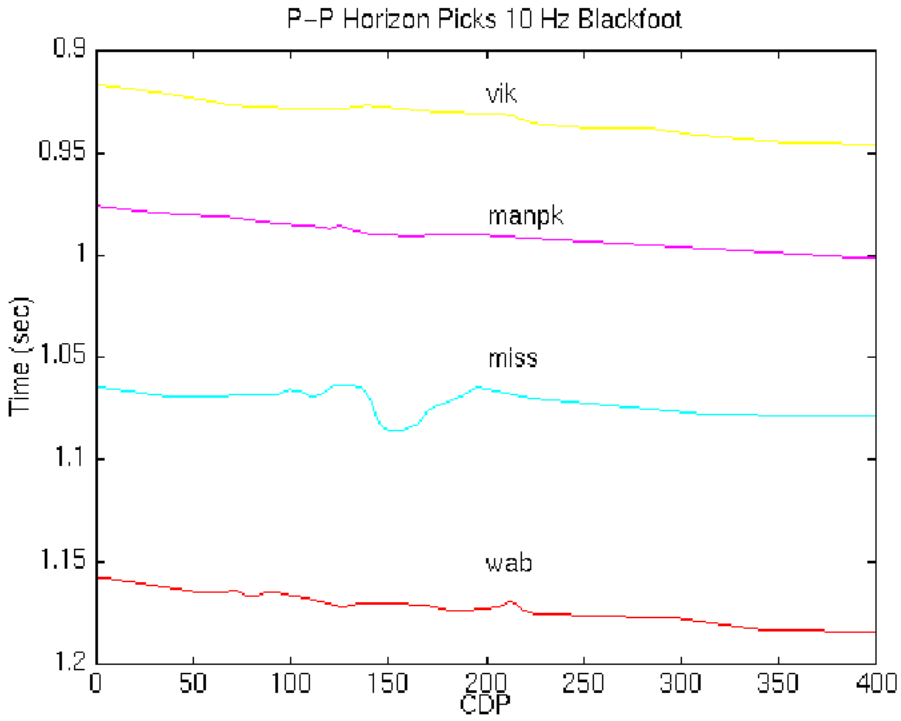


Fig. 5. Horizon picks for P-P data. These, in conjunction with the corresponding P-S horizon picks, were used to correlate P velocity and S-velocity estimate to P-S time for P-S inversion.

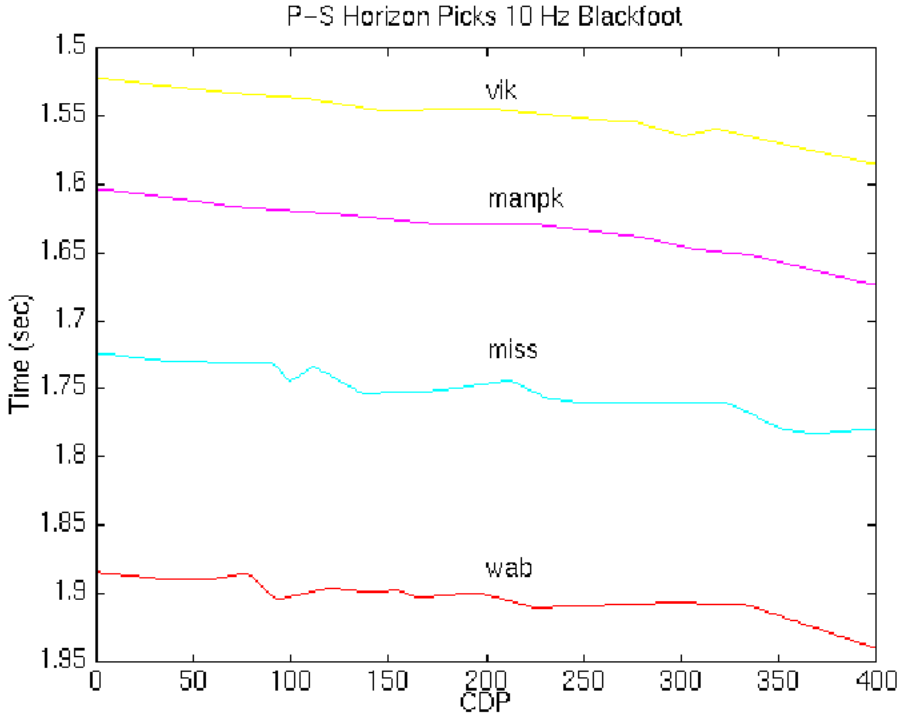


Fig. 6. Horizon picks for P-S data.

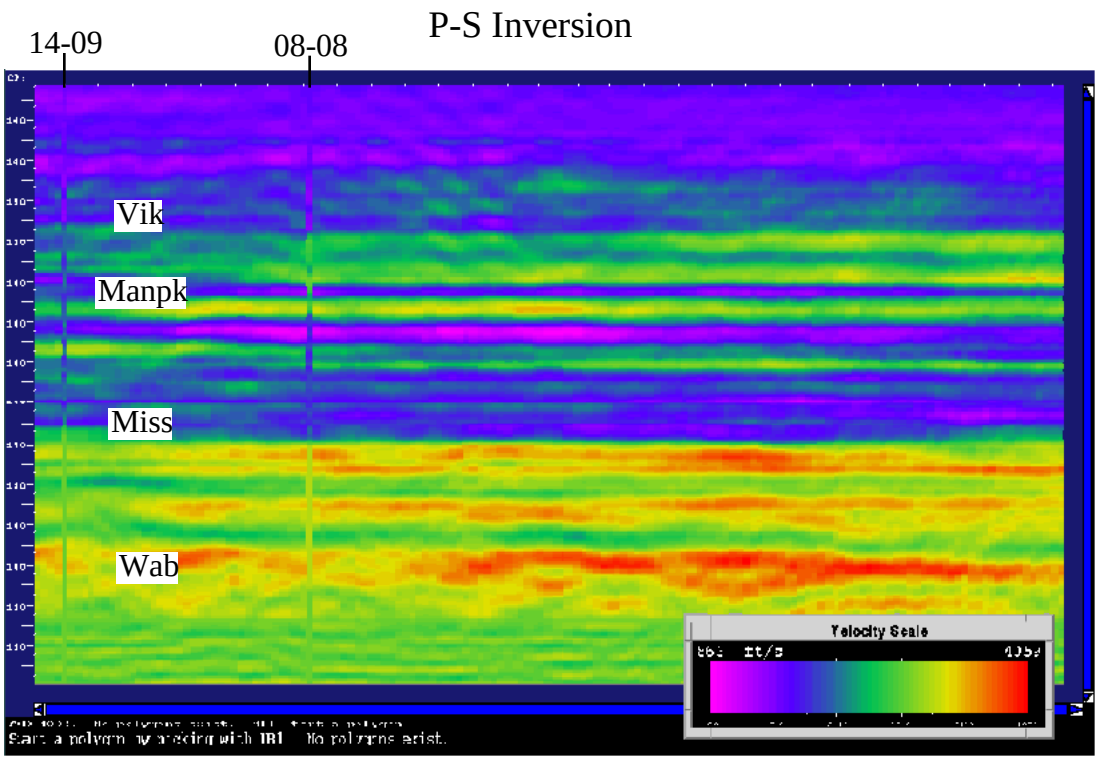


Fig. 7. Inversion of P-S data. S sonics 14-09 and 08-08 are overlain for comparison. The CDP range is 101 on the left and 251 on the right. The target channel, to the right of 08-08 at the Miss level, is much less evident than on the P-P inversion.

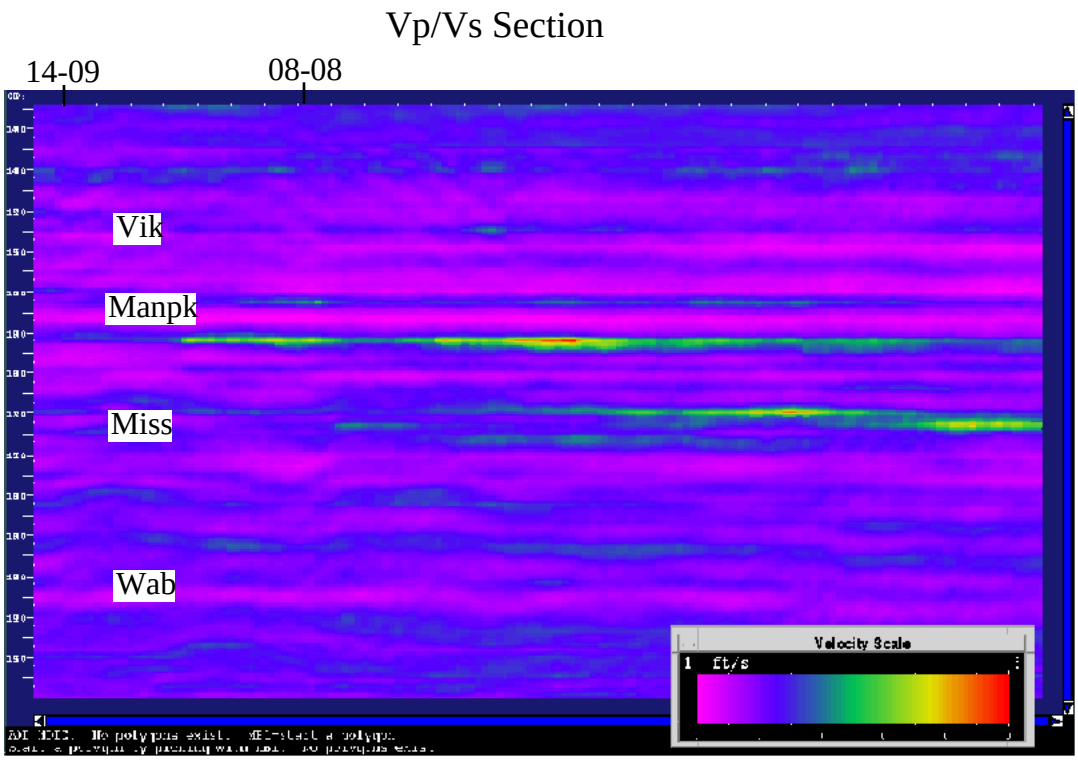


Fig. 8. Vp/Vs section. Values generally fall within reasonable levels, 1.5 - 2.5, with anomolously high values just below the Manpk.

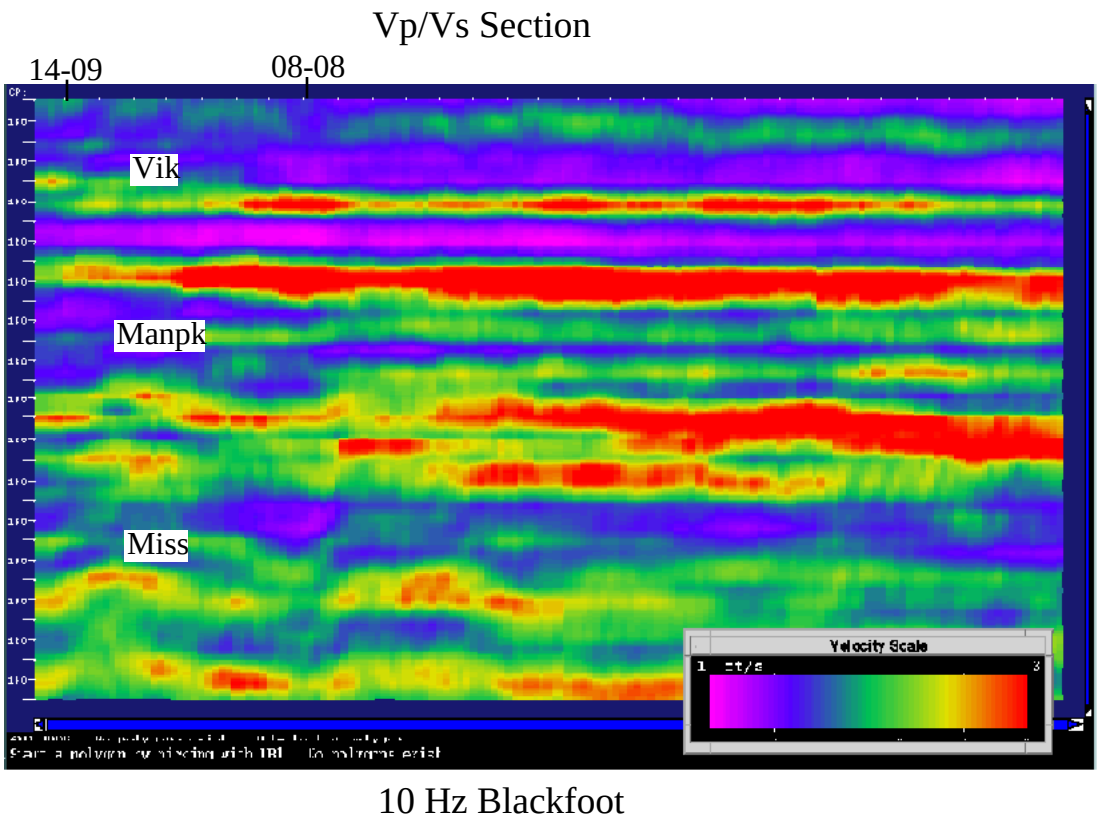


Fig. 9. Close up for Figure 8, with Vp/Vs ranges clipped at 3.0. Vp/Vs decrease visible across the target zone.